ANALYSIS

Vol. 21, Issue 68, 2020

ISSN 2319–5746 EISSN 2319–5754

Species

Plant colonization in Open Air Theatre of Andhra University, Visakhapatnam: An example of succession and initiation of ecosystem development

Solomon Raju AJ[1], **Venkata Ramana K**[2]

[1]Department of Environmental Sciences, Andhra University, Visakhapatnam 530 003, India
[2]Department of Botany, Andhra University, Visakhapatnam 530 003, India

✉**Corresponding author**:
A.J. Solomon Raju, Department of Environmental Sciences, Andhra University, Visakhapatnam 530 003, India;
Mobile: 91-9866256682, Email:solomonraju@gmail.com

Article History
Received: 12 June 2020
Accepted: 01 July 2020
Published: July 2020

Citation
Solomon Raju AJ, Venkata Ramana K. Plant colonization in Open Air Theatre of Andhra University, Visakhapatnam: An example of succession and initiation of ecosystem development. *Species*, 2020, 21(68), 249-260

General Note
Article is recommended to print as color digital version in recycled paper.

ABSTRACT

Plant colonization aspects in the Open Air Theatre of Andhra University have been investigated. The study recorded a total of 45 seasonal and year-long blooming species belonging to 23 families. Of these, 28 species were herbs, 3 shrubs, 1 climber, 1 creeper and 12 trees. Among these species, 33 are hermaphroditic, 8 monoecious, 2 andromonoecious and 1 each gynomonoecious and dioecious. Hermaphroditic species, especially herbs self-fertilize, produce seeds prolifically with or without pollen vectors and act as

colonizers. Plant species displaying other sexual systems are obligately vector-dependent for seed production and act as immigrants. Again, among these, 33 species produce dehiscent fruits, 4 species indehiscent fruits and 8 species fleshy fruits. Different fruit/seed dispersal modes are functional in these species. Each species uses 2-5 dispersal modes which enable them to move to new sites either by colonization or by immigration. The study site provided an opportunity to observe and understand the function of plant succession, and the plant species that act as colonizers and immigrants.

Key words:
Open Air Theatre, colonizers, immigrants, sexual systems, fruit types, seed dispersal.

1. INTRODUCTION

Plant colonization is the survival through germination and establishment. It includes diverse life history strategies involving stress tolerance, different germination strategies, fast-growing and high seed dispersal (Cadotte et al. 2006). Dispersal mode greatly influences the opportunity for species to disperse (Wilson et al. 2009; Gillespie et al. 2012). Intentional or accidental human-mediated dispersal of species accelerates the rate at which species colonize novel environments (Mack et al. 2000). Species naturally colonizing novel environments go through the same stages of reproduction, establishment and spread as species introduced by humans accidentally or intentionally because both forms of colonization are subject to the same barriers of survival, reproduction, dispersal and further range expansion (Yek and Slippers 2014). The plant species have been distinguished into three types, colonizers, immigrants and invaders by Bajaj (1986). According to him, colonizing species settle in open sites that is not yet occupied by other species and they do not experience any competition initially. Immigrant species do not significantly impede populations of colonizers already established and surviving in the open sites but integrate themselves into the existing community. Invading species penetrate natural, intact phytocoenoses, and dominate or displace certain species in the habitat. Such situations do not happen in urban habitats because the latter are influenced or created by human activities. In the present study, the plant species colonized through succession that led to the initiation of ecosystem development in Prof. K.V. Gopalaswamy Open Air Theatre in the south campus of Andhra University, have been provided along with their life form, sexual system, fruit form/dehiscence and dispersal modes based on a year-long study. This study explains how the plant species through their propagules (seeds) have arrived and established gradually over a period of more than three decades to produce the present state of ecosystem by colonization and immigration.

2. MATERIALS AND METHODS

In Andhra University, Prof. K.V. Gopalaswamy Open Air Theatre as an extension of the Department of Theatre Arts was constructed between 1957-1960. This theatre was previously known as Erskine Square Building (2-storey) because it was named after Lord Erskine, the then Chancellor of Andhra University. Inside the theatre, the floor of the seating area was made of concrete and permanent concrete benches were erected subsequently 1987. This theatre has been in use since then to stage plays and organize different academic and non-academic events including movie shootings. But, this theatre area was not properly maintained from time to time, and as a result the concrete stage and seating area developed cracks and crevices exposing the soil and sand beneath and also the iron inside got exposed. In course of time, the disintegrated and damaged concrete floor gradually paved the way for the colonization by pioneer and immigrant plant species. Added to this, this theatre was further damaged extensively during the landfall of the extensive severe cyclonic storm, *Hudhud* near Visakhapatnam on 12th October 2014. The severely damaged theatre facilitated for the rapid colonization and build up of populations of certain pioneer plant species followed by immigrant plant species (Figure 1a,b) .

The Andhra University has taken a decision to renovate the theatre as per global standards. Currently, this theatre is being renovated to bring back its lost glory in order to use it for various activities of the University (Figure 1c,d). The present study was conducted from January to December 2019. The plant species were enumerated to prepare the list according to the family, life form, sexual system, fruit dehiscence/dispersal and seed dispersal modes. Site observations were also made to understand the ability of the plant species colonized inside the Open Air Theatre area to show vegetative, flowering and fruiting events under moisture and nutrient stress conditions. Field surveys were made in the entire south campus of the Andhra University to have an idea about the sources of the plant species that colonized the theatre area. Further, the information collected on the aspects stated above from our field observations made on the same plant species outside this study area by the authors over a period of fifteen years was also used to understand the abilities of colonization and immigration by the noted plant species.

Figure 1. Open Air Theatre, Andhra University: a. & b. Prior to taking up renovation works, c. & d. During renovation work – c. View from the side of audience, d. View from the side of stage of the theatre.

3. OBSERVATIONS

The study revealed the occurrence of a total of 45 species belonging to 23 families in Open Air Theatre of Andhra University. Of the 23 families, Euphorbiaceae and Fabaceae were represented by 5 species each; Apocynaceae, Malvaceae, Molluginaceae, Moraceae by 3 species each; Acanthaceae, Amaranthaceae, Asteraceae, Commelinaceae and Rubiaceae by 2 species each; and all other families by 1 species each. Life form-wise, 28 species were herbs, 3 shrubs, 1 climber, 1 creeper and 12 trees (Figures 2-6). The herbs included annual and perennial erect/prostrate/diffuse/decumbent/ acaulescent forms. The shrubs were either erect or prostrate forms. The climber was herbaceous while the creeper was woody. The trees included evergreen/semi-evergreen/deciduous/semi-deciduous. Among all the life-forms, the herb, climber and creeper species were most common and colonized most of the area where floor concrete was damaged and soil exposed. The other life forms were sporadic in occurrence. The woody shrub and tree species were identified and listed based on the occurrence of their seedlings/saplings. In case of trees, only *Ficus* species are very distinct because of their fast growth and visibility even from a long distance.

Figure 2. a. *Annona squamosa*, b. *Wrightia tinctoria*, c. *Albizia lebbeck*, d. *Ceiba pentandra*, e. *Azadirachta indica*, f. *Ficus benghalensis, g. Ficus religiosa*, h. *Ziziphus mauritiana*, i. *Morinda tomentosa*, j. *Sapindus emarginatus*.

The recorded species were either seasonal or year-long bloomers. The seasonal bloomers included *Tabebuia rosea* (January-April; August-September), *Annona squamosa* (February-May), *Azadirachta indica, Morinda tomentosa* (March-June), *Wrightia tinctoria* (April-June), *Ficus benghalensis* and *F. religiosa* (April-July), *Albizia lebbeck*, *Aristolochia indica* (June-October), *Ziziphus*

mauritiana (July-October), *Ceiba pentandra*, *Hemidesmus indicus* (November-February) and *Tinospora cordifolia* (November-May). All other species bloom throughout the year with intense blooming during wet season (June-November). Outside wet season, the blooming intensity depends on the soil moisture and nutrient contents. Further, most of the herbs and also shrubs recruit new plants from seeds continuously during wet season and even during dry season depending on the soil environment.

Figure 3. a. *Calotropis gigantea*, b. *Desmodium incanum*, c. *Tinospora cordifolia*, d. *Andrographis echioides*, e. *Ruellia tuberosa*, f. *Trianthema portulacastrum,* g. *Achyranthes aspera*, h. *Pupalia leppacea*.

Figure 4. a. *Hemidesmus indicus*, b. *Aristolochia indica, c. Tridax procumbens*, d. *Vernonia cinerea*, e. *Cleome viscosa*, f. *Commelina benghalensis*, g. *Evolvulus nummularius*, h. *Acalypha indica*.

Of the total species recorded, 33 are hermaphroditic, 8 monoecious, 2 andromonoecious and 1 each gynomonoecious and dioecious. The monoecious species were represented by *A. indica, E. hirta, M. mercularis, P. maderaspatensis* and *P. niruri* - all belonging to Euphorbiaceae family, by A. *heterophyllus, F. benghalensis* and *F. religiosa* belonging to Moraceae family. The andromonoecious species included *C. benghalensis* and C. *longifolia*. The gynomonoecious species was *T. procumbens* (Asteraceae)

and dioecious species was *T. cordifolia* (Menispermaceae). The hermaphroditic species were represented by Acanthaceae, Aizoaceae, Annonaceae, Amaranthaceae, Apocynaceae, Aristolochiaceae, Asteraceae, Bignoniaceae, Cleomaceae, Convolvulaceae, Fabaceae, Lamiaceae, Malvaceae, Molluginaceae, Nyctaginaceae, Portulacaceae, Rhamnaceae, Rubiaceae and Violaceae.

Figure 5. a. *Euphorbia hirta*, b. *Micrococca mercurialis*, c. *Phyllanthus maderaspatensis*, d. *Desmodium triflorum*, e. *Tephrosia villosa*, f. *Ocimum americanum*, g. *Sida acuta,* h. *Sida cordifolia*.

Figure 6. a. *Mollugo cerviana*, b. *Mollugo nudicaulis*, c. *Mollugo pentaphylla*, d. *Boerhavia diffusa*, e. *Oldenlandia corymbosa*, f. *Hybanthus ennaespermus*.

Table 1. List of plant species recorded in the Open Air Theatre of Andhra University

Sl. No.	Family	Plant species	Habit	Sexual system	Fruit type	Seed dispersal modes
1.	Acanthaceae	*Andrographis echioides* (L.) Nees	Annual erect herb	Bisexual	Dehiscent capsule	Autochory Anemochory Hydrochory
2.	Acanthaceae	*Ruellia tuberosa* L.	Perennial erect herb	Bisexual	Dehiscent capsule	Autochory Anemochory Hydrochory
3.	Aizoaceae	*Trianthema*	Annual	Bisexual	Dehiscent	Autochory

		portulacastrum L.	prostrate herb		capsule	Barochory Hydrochory
4.	Annonaceae	*Annona squamosa* L.	Semi-evergreen tree	Bisexual	Fleshy Berry	Zoochory Anthropochory Barochory Hydrochory
5.	Amaranthaceae	*Achyranthus aspera* L.	Perennial Erect to spreading herb	Bisexual	Dehiscent utricle	Anemochory Zoochory Anthropochory Hydrochory
6.	Amaranthaceae	*Pupalia leppacea* (L.) Juss.	Perennial erect herb	Bisexual	Indehiscent Achene	Zoochory Barochory Hydrochory Anthropochory
7.	Apocynaceae	*Calotropis gigantea* (L.) Dryand var. *alba*	Perennial evergreen shrub	Bisexual	Dehiscent follicle	Autochory Anemochory Hydrochory
8.	Apocynaceae	*Hemidesmus indicus* (L.) R. Br.	Perennial woody climber	Bisexual	Dehiscent follicle	Autochory Anemochory Hydrochory
9.	Apocynaceae	*Wrightia tinctoria* (Roxb.) R.Br.	Deciduous tree	Bisexual	Dehiscent pendulous follicles	Autochory Anemochory Hydrochory
10.	Aristolochiaceae	*Aristolochia indica* L.	Perennial creeper	Bisexual	Dehiscent capsule	Autochory Anemochory
11.	Asteraceae	*Tridax procumbens* L.	Prostrate perennial herb	Gyno-monoecious	Cypsela	Anemochory Zoochory Anthropochory
12.	Asteraceae	*Vernonia cinerea* (L.) Less.	Erect annual herb	Bisexual	Cypsela	Anemochory Zoochory Anthropochory
13.	Bignoniaceae	*Tabebuia rosea* DC.	Deciduous tree	Bisexual	Dehiscent capsule	Autochory Anemochory
14.	Cleomaceae	*Cleome viscosa* L.	Annual herb	Bisexual	Dehiscent capsule	Autochory Anemochory Hydrochory
15.	Commelinaceae	*Commelina benghalensis* L.	Perennial spreading herb	Andro-monoecious	Dehiscent capsule	Autochory Anemochory Hydrochory
16.	Commelinaceae	*Commelina longifolia* Lam.	Perennial decumbent herb	Andro-monoecious	Dehiscent capsule	Autochory Anemochory Hydrochory
17.	Convolvulaceae	*Evolvulus nummularius* L.	Prostrate perennial herb	Bisexual	Dehiscent capsule	Autochory Anemochory Hydrochory
18.	Euphorbiaceae	*Acalypha indica* L.	Erect annual herb	Monoecious	Dehiscent capsule	Anemochory Hydrochory
19.	Euphorbiaceae	*Euphorbia hirta* L.	Erect annual herb	Monoecious	Dehiscent capsule	Autochory Anemochory Zoochory Hydrochory

						Barochory
20.	Euphorbiaceae	*Micrococca mercurialis* (L.) Benth.	Erect annual herb	Monoecious	Dehiscent capsule	Autochory Anemochory Zoochory Hydrochory
						Barochory
21.	Euphorbiaceae	*Phyllanthus maderaspatensis* L.	Erect annual herb	Monoecious	Dehiscent capsule	Autochory Anemochory Zoochory Hydrochory
						Barochory
22.	Euphorbiaceae	*Phyllanthus niruri* L.	Erect annual herb	Monoecious	Dehiscent capsule	Autochory Anemochory Zoochory Hydrochory
						Barochory
23.	Fabaceae	*Albizia lebbeck* (L.) Benth.	Deciduous tree	Bisexual	Dehiscent pod	Autochory Anemochory Barochory Hydrochory
24.	Fabaceae	*Desmodium incanum* DC.	Perennial prostrate shrub	Bisexual	Indehiscent pod	Zoochory Barochory Hydrochory
25.	Fabaceae	*Desmodium triflorum* (L.) DC.	Prostrate creeping herb	Bisexual	Indehiscent pod	Zoochory Barochory Hydrochory
26.	Fabaceae	*Leucaena leucocephala* (Lam.) de Wit	Semi-deciduous tree	Bisexual	Dehiscent pod	Autochory Anemochory Barochory Hydrochory
27.	Fabaceae	*Tephrosia villosa* (L.) Pers.	Erect perennial herb	Bisexual	Dehiscent pod	Autochory Anemochory Barochory Hydrochory
28.	Lamiaceae	*Ocimum americanum* L.	Erect perennial herb	Bisexual	Schizocarp	Autochory Anemochory Barochory Hydrochory
29.	Malvaceae	*Ceiba pentandra* (L.) Gaertn.	Deciduous tree	Bisexual	Dehiscent capsule	Anemochory Hydrochory
30.	Malvaceae	*Sida acuta* Burm.f.	Erect annual herb	Bisexual	Dehiscent capsule	Anemochory Hydrochory Zoochory
31.	Malvaceae	*Sida cordifolia* L.	Erect annual herb	Bisexual	Dehiscent capsule	Anemochory Hydrochory Zoochory
32.	Meliaceae	*Azadirachta indica* A. Juss.	Deciduous/ evergreen tree	Bisexual	Fleshy drupe	Zoochory Anthropochory Barochory
33.	Menispermaceae	*Tinospora cordifolia* (Thunb) Miers.	Deciduous perennial	Dioecious	Fleshy drupe	Barochory Zoochory

			climbing shrub			Anthropochory
34.	Molluginaceae	*Mollugo cerviana* (L.) Ser.	Erect annual herb	Bisexual	Dehiscent capsule	Autochory Anemochory Ombrohydrochory Barochory Hydrochory
35.	Molluginaceae	*Mollugo nudicaulis* Lam.	Acaulescent annual herb	Bisexual	Dehiscent capsule	Autochory Barochory Anemochory Ombrohydrochory Hydrochory
36.	Molluginaceae	*Mollugo pentaphylla* L.	Erect annual herb	Bisexual	Dehiscent capsule	Autochory Barochory Anemochory Ombrohydrochory hydrochory
37.	Moraceae	*Artocarpus heterophyllus* Lam.	Evergreen tree	Monoecious	Fleshy syncarp	Zoochory Anthropochory
38.	Moraceae	*Ficus benghalensis* L.	Semi-evergreen tree	Monoecious	Fleshy syconium	Zoochory Anthropochory Barochory Hydrochory
39.	Moraceae	*Ficus religiosa* L.	Semi-evergreen tree	Monoecious	Fleshy syconium	Zoochory Anthropochory Barochory Hydrochory
40.	Nyctaginaceae	*Boerhavia diffusa* L.	Prostrate perennial herb	Bisexual	Indehiscent capsule	Barochory Zoochory Anthropochory Hydrochory
41.	Portulacaceae	*Portulaca oleracea* L.	Prostrate annual herb	Bisexual	Dehiscent capsule	Autochory Anemochory Zoochory Hydrochory
42.	Rhamnaceae	*Ziziphus mauritiana* Lam.	Deciduous tree	Bisexual	Fleshy drupe	Zoochory Anthropochory Barochory Hydrochory
43.	Rubiaceae	*Morinda tomentosa* B. Heyne ex Roth	Evergreen tree	Bisexual	Fleshy syncarpium capsule	Zoochory Barochory Hydrochory
44.	Rubiaceae	*Oldenlandia corymbosa* L.	Diffuse annual herb	Bisexual	Dehiscent capsule	Autochory Anemochory Barochory Ombrochory Hydrochory
45.	Violaceae	*Hybanthus enneaspermus* (L.) F. Muell.	Diffuse perennial herb	Bisexual	Dehiscent capsule	Autochory Anemochory Anthropochory Hydrochory

The fruit types of all the recorded species represented dehiscent capsule/utricle/follicle/pod/schizocarp/cypsela (33 species), indehiscent achene/capsule/pod (4 species) and fleshy berry/drupe/syncarp/syncarpium/synconia (8 species).

Fruits are capsules in *A. echioides, R. tuberosa* (Acanthaceae), *T. portulacastrum* (Aizoaceae), *A. indica* (Aristolochiaceae), *T. rosea* (Bignoniaceae), *C. viscosa* (Cleomaceae), *C. benghalensis, C. longifolia* (Commelinaceae), *E. nummularius* (Convolvulaceae), *E. hirta, M. mercularis, P. maderaspatensis, P. niruri* (Euphorbiaceae), *C. pentandra, S. acuta, S. cordifolia* (Malvaceae), *M. cerviana, M. nudicaulis, M. pentaphylla* (Molluginaceae), *P. oleracea* (Portulacaceae), *O. corymbosa* (Rubiaceae) and *H. enneaspermus* (Violaceae); utricle in *A. aspera (*Amaranthaceae); follicles in *C. gigantea, H. indicus* and *W. tinctoria* (Apocynaceae); and pods in A. *lebbeck, L. leucocephala* and *T. villosa* (Fabaceae). Fruit is cypsela type in *T. procumbens* and *V. cinerea* while it is schizocarp type in *O. americanum*. In *A. echioides*, the capsule fruit bursts open into two valves with a jerk and the seed is projected with the aid of a jaculator enabling it to be dispersed at a great speed. In *R. tuberosa*, the dry capsules break open with force when rain water drops fall on the capsule. In this process, the capsule spontaneously ejects seeds for dispersal; the curved hooks or jaculators of the seeds cause the latter to eject explosively from the capsule. In *T. portulacastrum*, the capsule has a single awn at the tip opening around the middle portion where seeds are located. During dehiscence, one seed is carried away on the detached cap of the capsule while other seeds fallout from the remaining part. Further, the seeds are carried away by rain water during wet season. In *A. indica*, the capsule is 6-valved and shallow grooved with several tightly packed triangular winged seeds; when the capsule splits open, it appears like an inverted parachute with seeds dispersed by wind. In *T. rosea*, the dry capsule splits into two halves exposing the hyaline-membrane-winged seeds attached to the central wall. Then, the seeds disperse by wind. In *C. viscosa*, the capsules dehisce septicidally from the tip to the base to release seeds into the air which are simultaneously and/or subsequently dispersed by wind during dry season and by rain water during rainy season. In *Commelina* species, the pear-shaped capsule with five seeds produced from the chasmogamous flowers of sub-aerial shoots dehisce and disperse seeds by wind. The capsule produced from cleistogamous flowers of sub-terranean shoots disperse seeds into the soil. Further, the seeds produced from both types of flowers also disperse by rain water. In *E. nummularius*, the capsule dehisces loculicidally dipsersing seeds into the air, which either spontaneously or subsequently disperse by wind during dry period and also by water during wet season. In Euphorbiaceae, the fruit in all recorded species is a 3-lobed globose capsule and dehisces septicidally exposing seeds which disperse by several modes such as falling to the ground by gravity, by wind, birds and water. In *C. pentandra*, the capsule is 5-valved and dehisces releasing numerous seeds which are equipped with copious white silky fibers enabling them for dispersal by wind during dry period and also by rain water during wet period. In *Sida* species, the fruit capsule dehisces loculicidally to release seeds; it splits open into 6 one-seeded segments in *S. acuta* and 10 one-seeded segments in *S. cordifolia*. The seeds are wedge-shaped with two sharp awns and easily disperse by air and upon reaching the ground by rain water. Further, the seeds also disseminate by attaching to the fur of animals and to the clothes of humans. In *Mollugo* species, the fruit is a loculicidal 3-valved capsule with reniform seeds arranged in two rows in each locule. It breaks open to release seeds which fall to the ground by gravity and disperse by wind; the seeds are also washed out when water droplets fall on the dehisced capsules and they also migrate to new sites by rain water. In *P. oleracea*, the capsule is many-seeded and dehisces around circumference exposing seeds which disperse by wind, birds and rainwater. In *O. corymbosa*, the capsule is globose and dehisces loculicidally into valves exposing the seeds which then disperse by wind, falling to the ground by gravity and by water. Further, the rain water drops splashing on the capsules not dehisced also cause them to dehisce due to which seeds reach the ground. In *H. ennaespermus*, the fruit capsule is 3-valved and dehisce to release seeds which are then dispersed by wind, water and humans. In *A. aspera*, the fruit capsule is a 1-seeded utricle enclosed in a persistent sharp-pointed perianth. The fruits disperse by wind, rain water and by sticking to hair of animals and clothes and footwear of humans. In Apocynaceae, the fruit in recorded species is a follicle and dehisces vertically exposing the seeds, which are then dispersed by wind and migrate to new sites by rain water. In *A. lebbeck, L. leucocephala* and *T. villosa*, the fruit is a linear flattened pod but it is slightly curved at the tip in the last species. The fruits twist slightly in the first two species and twist spirally in the last two species to dehisce and disperse seeds. The seeds are also dispersed by falling to the ground by gravity, by wind and water. In Asteraceae species, the fruit is 1-seeded cypsela tipped with pappus of white silky hairs and it ejects out from the from the fruiting calyx for dispersal by wind, animals and humans. The seeds settled on the ground disperse also by rain water. In *O. americanum*, the fruit is a schizocarp composed of 4 distinct nutlets enclosed within the tube of the persistent calyx. The dry fruiting calyx ejects seeds to fall to the ground by gravity and also the individual schizocarp or the entire fruited inflorescence disperse by wind and rainwater.

Fruit is achene type in *P. leppacea* (Amaranthaceae), capsule type in *B. diffusa* (Nyctaginaceae) and pod type in *D. incanum* and *D. triflorum* (Fabaceae). The fruit types of these species are indehiscent and not self-dispersing. In these species, the dry fruits fall by gravity within the vicinity of parental plants (barochory) and disperse by rain water during wet season (hydrochory). In *P. leppacea*, the seed-head is burred, sharp and stick to fur of animals or clothing and as a result the seeds are transported to new sites by

animals (zoochory) and humans (anthropochory). In *B. diffusa*, the fruit is small, sticky, 1-seeded and is formed by the calyx which closes at the top. It detaches easily and stick to fur of animals, clothing and also to the feathers of birds. The animals, humans and birds passing by the plant area easily catch the fruits and transport to new sites. In *Desmodium* species, the pod breaks apart transversely into 1-seeded segments covered with rough sticky hairs, separate easily and adhere to fur of animals and clothing. The animals and humans passing by these shrubby species catch the segments of the pod and transport to new sites.

Fruits are fleshy syncarps in *A. squamosa* (Annonaceae) and *A. heterophyllus* (Moraceae) fleshy drupes in *A. indica* (Meliaceae), *T. cordifolia* (Menispermaceae), *Z. mauritiana* (Rhamnaceae), fleshy syncarpium capsule in *Morinda tomentosa* (Rubiaceae) and fleshy syconia in *Ficus* species (Moraceae). The fruit types of these species are not self-dispersing. All these species except *M. tomentosa* are edible. In *A. squamosa*, the fruit is composed of many ovaries of a single flower fused together forming a fleshy aggregated syncarp. In *A. heterophyllus,* the syncarp produced from female flowers is many-seeded. In *A. indica*, the fruit is pulpy and 1-seeded. The fruit in *T. cordifolia* is a succulent drupe with 1-seeded curved seed. *Z. mauritiana* fruits are fleshy and 1-seeded. In *M. tomentosa*, the syncarpium fruit with many false 1-seeded pyrenes is fleshy due to coalescence of succulent calyx. In *Ficus* species, the fleshy syconium fruit is formed from many female flowers in the hypanthodium and hence is many-seeded. Fruit/seed dispersal modes included zoochory and anthropochory in *A. heterophyllus*, zoochory, barochory and hydrochory in *M. tomentosa*, and zoochory, anthropochory, barochory and hydrochory in all other species.

4. DISCUSSION

Bajaj (1986) distinguished the plant species into colonizer, immigrant and invader types. The colonizing species occupy open sites that have not been occupied earlier by other species. Immigrant species integrate themselves into the colonized communities without much impediment to them. Invading species usually penetrate the natural habitats and subsequently dominate or displace the existing species. Since the urban habitats are consistently subjected to influences by human activities, invading species, even if arrive there, cannot influence the existing species either by dominance or by displacement. The present study shows that the plant species recorded belong to either colonizer or migrant type only. The plant species with dehiscent type fruit capsules are autochorous resulting in either barochory or anemochory. Euphorbiaceae species and *P. oleracea* also display ornithochory while *Sida* spp., *H. ennaespermus*, *A. aspera* and Asteraceae species display zoochory (animals) and anthropochory. *O. corymbosa* is also ombrochorous and *Mollugo* spp. are also ombrohydrochorous. Further, all autochorous species are hydrochorous. Chothani et al. (2010) reported that jaculator-cum-explosive mechanism is functional in *R. tuberosa* and the present study also substantiates the same. Further, these authors also reported that ombrohydrochory is also functional in *R. tuberosa*. Kreitschitz (2012) and Kreitschitz and Valles (2007) reported that *O. americanum* seeds have mucilage secreting cells as an integrative part of seed coat and produce a thick white cover of slimy mucilage upon touch with water by hydration. The ability of the seed coat to form the mucilage when in touch with water is an adaptation of the plant to survive in dry or disturbed habitats. In this study, it is found that mucilage production by the seeds of this plant species when in touch with moisture enables it to survive in water stress situations. Among autochorous species, *T. rosea, C. pentandra, W. tinctoria, A. lebbeck* and *L. leucocephala* are tree species and act as immigrants while all other species act as colonizers. The plant species with indehiscent fruit capsule type are *P. leppacea, B. diffusa* and *Desmodium* spp. being non-autochorous use barochory, zoochory and anthropochory as fruit dispersal modes. Different authors reported that *D. incanum* has hitchhiking hairy seed pods as they easily stick to the fur of animals and clothing of humans (Mori and Brown 1998; Trzeciak-Limeira et al. 2013) making this species well adapted to epizoochorous dispersal (Barroso et al. 1999). In this study also, *D. incanum* has been found to be adapted also for epizoochory. The plant species with fleshy or succulent fruit type are all trees which include *A. squamosa*, *A. heterophyllus*, *A. indica*, *T. cordifolia*, *Z. mauritiana*, *Morinda tomentosa* and *Ficus* species. These species being non-autochorous display different fruit dispersal modes. Zoochory is functional in *A. heterophyllus* while barochory, zoochory and hydrochory in all other species. Additionally, anthropochory is also an important dispersal mode in these species except *M. tomentosa*. Chamberlain (2000) reported that frugivorous birds and bats play an important role in seed dispersal of *A. indica*. In the study area, bats have never been found to be using fruits of *A. indica* but frugivorous birds act as its seed dispersers. Midya and Brahmachary (1991) noted that *F. benghalensis* fruits are dispersed by frugivorous birds and mammals. In the study area, only frugivorous birds use fruits of this species as food source and in the process act as seed dispersers through their excreta dropping. Gardiner and Gardiner (1996) and Grice (1996; 1998) mentioned that *Z. mauritiana* is primarily dispersed by birds, wild animals, livestock and humans. In this study, only birds and humans have been found to be seed dispersal agents of this tree species. The plant species with indehiscent fruit capsule type and fleshy/succulent fruit type act as immigrants. The functionality of multiple fruit or seed dispersal modes in all these species is inevitable since each dispersal mode has its own limitations. Autochory is basically a self-dispersal strategy which disperses seeds to a limited distance, usually within the vicinity of parental plants. Anemochory is an extension of autochory to disperse seeds to different distances depending on the wind speed prevalent at that time; it is most

effective only during dry ambient conditions, which exist usually during dry season. Autochory also results in barochory in several plant species. Ombrochory, ombrohydrochory and hydrochory modes of dispersal are functional only during wet season or when rains occur. Zoochory and anthropochory are dependent on the availability of animals that use fruits or seeds as their food and of humans who come in contact with anthropochorous fruits or seeds. Therefore, multiple modes of seed dispersal are essential for plant colonizers and immigrants to occupy new and novel sites.

Pannell (2015) stated that colonization involves the establishment of a new population in habitats not occupied by its species. In new habitats, the colonizer species have the opportunity to increase per-individual reproductive success because of reduced crowding of its own or other plant species and the increase in reproductive success could compensate against the loss of local adaptation. Further, colonization is likely to be more successful for species with an ability to self-fertilize and establish new populations of its species as single individuals. The present study shows that most of the plant species, especially herbs are hermaphroditic and the prolific seed output observed in these species indicate that they self-fertilize with or without pollen vectors. Monoecious, andromonoecious and gynomonoecious species in the study area are not prolific seed producers since biotic or abiotic pollen vectors are essential for pollen transport between male and female flowers. These species with different sexual systems and even if they self-fertilize (between flowers on the same plant) require pollinators. Further, the dioecious species *T. cordifolia* is obligately dependent on pollen vectors for pollination. Therefore, self-fertilizing hermaphroditic species with the ability to produce prolific seed output colonize the new habitats quickly and act as colonizers while all other species recorded in this study could act as immigrants only.

The seasonal flowering in *T. rosea*, *A. squamosa*, *A. indica, M. tomentosa*, *W. tinctoria*, *F. benghalensis* and *F. religiosa*, *A. lebbeck*, *A. indica*, *Z. mauritiana*, *C. pentandra*, *H. indicus* and *T. cordifolia* also does not enable them to produce massive fruiting to colonize new sites and hence can act as immigrants only and integrate themselves into the colonized communities. All other species recorded in this study, with annual or perennial herbaceous habit that have the flexibility to flower and fruit throughout the year even under moisture and nutrient stress with multiple modes of fruit/seed dispersal act as pioneer species and colonize new sites, in the present case, the damaged concrete floor. The pioneer-cum-colonizing species with year-long fruiting are prolific seed producers and produce seeds continuously and most of them germinate immediately if the soil environment favourable. Among tree species, several individuals of *Ficus* spp. of 1 m to 2m length occur and dominate by their fast growth; their arrival here is exclusively through frugivorous birds feeding on their fruits available on the trees growing in several areas of Visakhapatnam. The study findings agree with Cadotte et al. (2006) that stress tolerance, different germination strategies, fast-growing and high seed dispersal strategies are the traits of plant colonizers and with Wilson et al. (2009) and Gillespie et al. (2012) that dispersal modes influence the opportunities for species to disperse to new areas. Further, the study also finds that human-mediation with anthropochorous fruits or seeds accidentally or intentionally accelerates the colonization rate in new or novel environments (Mack et al. 2000; Yek and Slippers 2014).

5. CONCLUSION

The study indicates that the study site with disintegrated and damaged concrete floor over a period of more than three decades provided the opportunities for colonizing and immigrant species to occupy and produce new populations or individuals. The assemblage of plant species and the ground cover collectively called "vegetation" that exists in this area is an outcome of the function of process of succession. The present state of the vegetation shows initial signs of ecosystem development as it integrated all life forms into its fabric and if this vegetation is allowed undisturbed or untouched would certainly move forward to form a stable ecosystem within the Open Air Theatre. But, the Theatre is not meant for this purpose and hence it is not appropriate to have vegetation cover here. However, the present state of vegetation recorded provided an opportunity to observe and understand the function of plant succession, and the plant species that act as colonizers and immigrants.

Acknowledgement

We thank the Andhra University, Visakhapatnam, for providing all physical facilities to carry out this research work.

Authors contributions: Both authors contributed equally.

Funding

This research received no external funding.

Conflict of interest

No potential conflict of interest regarding the manuscript.

REFERENCE

1. Bajaj, F.A. 1986. Life history of colonizing plants: some demographic, genetic, and physical features. Ecology of biological invasions of North America and Hawaii. H.A. Mooney and J.A. Drake (eds.), pp. 96-110, Springer-Verlag, New York.
2. Barroso, G.M., Morim, M.P., Peixoto, A.L. and Ichaso, C.L.F. 1999. Frutos e Sementes" Morfologia Aplicada a Sistematica de Dicotiledoneas. Vicosa, Editora UFV.
3. Cadotte, M.W., Mai, D.V., Jantz, S., Collins, M.D., Keele, M., & Drake, J.A. 2006. On testing the competition-colonization trade-off in a multispecies assemblage. The American Naturalist, 168, 704–709.
4. Chamberlain, J. 2000. Framework for monitoring invasive tree species in Ghana. Oxford, UK, Center for Natural Resources and Development, Green College. http: www.green.ox.ac.uk/cnrd/jo.htm.
5. Chothani, D.L., Patel, M.B., Mishra, S.H. and Vaghasiya, H. 2010. Review on Ruellia tuberosa (Craker plant). Phcog J. 2: 506-512.
6. Gardiner, C.P. and Gardiner, S.P. 1996. The dissemination of chinee apple (Ziziphus mauritiana: a woody weed of the tropical sub-humid savanna and urban fringe of north Queensland. Trop. Grasslands 30: 174.
7. Gillespie, R.G., Baldwin, B.G. Waters, J.M., Fraser, C.I., Nikula, R., Roderick, G.K. 2012. Long-distance dispersal: a framework for hypothesis testing. Trends in Ecol. and Evol. 27: 46-56.
8. Grice, A.C. 1998. Ecology in the management of Indian jujube (Ziziphus mauritiana). Weed Sci. 46: 467-474.
9. Grice, A.C. 1996. Seed production, dispersal and germination in Cryptostegia grandiflora and Ziziphus mauritiana, two invasive shrubs in tropical woodlands of northern Australia. Austr. J. Ecol. 21: 324-331.
10. Kreitschitz, A. 2012. Mucilage formation in selected taxa of the genus Artemisia L. (Asteraceae, Anthemideae). Seed Sci. Res. 22: 177-189.
11. Kreitschitz, A. and Valles, J. 2007. Achene morphology and slime structure in some taxa of Artemisia L. and Neopallasia L. (Asteraceae). Flora 202: 570-580.
12. Mack, R.N., Simberloff, D., Lonsdale, W.M., Evans, H., Clout, M. and Bazzaz, F.A. 2000. Biotic invasions: causes, epidemiology, global consequences and control. Ecol. Appl. 10: 689-710.
13. Midya, S. and Brahmachary, R.L. 1991. The effect of birds upon germination of Banyan (Ficus benghalensis) seeds. J. Trop. Ecol. 7: 537-538.
14. Mori, S.A. and Brown, J.L. 1998. Epizoochorous dispersal by barts, hooks, and spines in a lowland moist forest in central French Guiana. Brittonia 50: 165-173.
15. Pannell, J.R. 2015. Evolution of the mating system in colonizing plants. Invasion genetics: The Baker and Stebbins legacy. Molecular Ecol. 24: 2018-2037.
16. Trzeciak-Limeira, F., Pinto, D.D. and Mourao, K.S.M. 2013. Pericaro ontogenesis with emphasis on the dispersal apparatus of three weed species of Faboideae (Fabaceae). Acta Botanica Brasilica 27: 723-729.
17. Wilson, J.R.U., Dormontt, E.E., Prentis, P.J., Lowe, A.J. and Richardson, D.M. 2009. Something in the way you move: dispersal pathways affect invasion success. Trends in Ecol. and Evol. 24: 136-144.
18. Yek, S.H. and Slippers, B. 2004. Biocontrol opportunities to study microevolution in invasive populations. Trends in Ecol. and Evol. 29: 429-430.